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DESIGN-TO-COST: AN EXAMINATION OF ITS USE IN WEAPON SYSTEM ACQUISITIONS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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Captain, USAF

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August 1973

Approved for public release;
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Captain Ray P. Linville

and

First Lieutenant Warren M. Rose

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CHAPTER I

FRAMEWORK OF DESIGN-TO-COST

Problem Statement

In an attempt to reduce the costs of weapon system acquisitions, the Department of Defense (DoD) has adopted as part of its procurement strategy the concept of design-to-cost. However, limited information is available concerning the concept and its application to military procurement. Uncertainty exists as to what the concept means, how it differs from previous DoD procurement strategies, and how it should be implemented in system acquisition programs.

Problem Summary

Before presenting the organization of this study, this chapter will present a brief discussion of the cost problems facing DoD, the origin of design-to-cost, and the basic elements of the concept. This is to familiarize the reader with the basic framework of design-to-cost.

Concern Over Increased System Acquisition Cost

The budgetary pressures and cost challenges of the 1970's have caused a real need for increased management attention to acquisition costs in the view of many DoD officials. According to Leonard Sullivan, Jr., Principal Deputy Director of Defense Research and Engineering:

> There is no way to reallocate resources within foreseen budget limitations to match the currently planned force levels with currently planned equipment costs and retain technological superiority in all of our forces at the same time. (42)

However, budget limitation is only one aspect of the problem; the other is the ever rising cost of weapon systems.

The myth of an ever increasing defense budget has been labeled false in a study of defense spending prepared by the Assistant Secretary of Defense (Comptroller). Defense spending for fiscal year (FY) 1973 in dollars of constant buying power will be at the lowest level since FY 1951. In addition, none of the real growth in the U.S. economy has been allocated to defense needs. For example, the defense share of the Gross National Product (GNP), of the U.S. labor force, and of the federal budget is at the lowest level since FY 1950. (55:i) The established trend of decreasing defense purchasing power is expected to continue throughout the 1970's. "The total estimated dollar increases between FY 73 and FY 80 will be consumed by anticipated inflation." (42)

The problem of decreased purchasing power is further

compounded because the funds available for procurement and for research and development will be limited due to rising costs in manpower and operations and maintenance. (24:18) Between FY 1961 and FY 1973, pay costs rose by $24 billion, although manpower declined. Operation costs increased by $5.2 billion. However, the remainder of the budget, including funds for system acquisitions, only increased by approximately $2 billion. (55:i) Mr. Sullivan expects

> ...military personnel and retirement costs will continue to increase, reaching 40% of the total (defense) budget by 1980. This assumes no change in force level. Operations and maintenance will also show growth in dollars to about 20% of the defense budget. (42)

Thus the funds available for new weapon systems development and production will continue to be extremely limited. DoD needs "an average of $13.5 billion annually to maintain a constant-size, constant-age inventory of weapons, which is approximately 60% more than the $8.5 billion now expected to be available." (24:18) The impact of limited development funds has already taken effect. Although the U.S. research and development capability has grown enormously, defense-related research and development was smaller in 1972 than any year since 1957. (55:iii)

The other side of the picture is the ever increasing unit costs of major systems. Weapon system costs are increasing by a factor of 10 every 20 years. (42) Dr. John S. Foster, Director of Defense Research and Engineering, has stated that DoD

> ...can no longer continue to buy adequate quantities of needed

> weapons if the unit procurement and lifetime costs of those weapons continue to soar.... We cannot compete with our major rivals on numbers and performance. (17)

If unit costs continue to escalate, then DoD will "have to procure less than the best..., if the best is too expensive to procure." (17)

Origin of the Design-to-Cost Concept

Congress has become increasingly concerned with rising defense system costs. It has questioned DoD's capability to manage acquisition programs and to provide the systems necessary to meet defense requirements. Due to several acquisitions in the 1960's which resulted in tremendous cost growth and a subsequent reduction in the number of units procured, DoD and the Senate Armed Services Committee began an examination of defense acquisition policy. The result was the establishment of the following procurement policies:

1. Reducing concurrency
2. Designing to cost requirements
3. Using prototypes
4. Requiring hardware competition
5. Reducing radically the size of industry design teams
6. Minimizing the number of detailed weapon system requirements
7. Increasing independent OT&E [operation, test, and evaluation] prior to a procurement decision. (17)

The advent of these new policies spelled the demise of the total package procurement concept, the procurement philosophy used during the latter half of the 1960's. Total package procurement was, in effect, a single point decision strategy calling for a single decision at the beginning of a system program to commit the system to one contractor for development, production, and follow-on support. In its place, DoD initiated a strategy which requires successful system review at the end of each stage of the acquisition process prior to commitment to the next stage.

The incremental acquisition strategy that DoD has adopted can be compared to the product development process used in private industry. Generally, when a private firm initiates a new product, it first assigns the product to a small team of personnel from engineering, manufacturing and marketing. (57:6) The team develops estimates of required technology, market impact, and manufacturing requirements as well as their associated costs. Executive management reviews the project team's findings at specified intervals during the development process. At each of these review points, price and return on investment are compared with the expected cost of production. The program proceeds to the next stage of development if projected net revenue and production costs are satisfactory. If they are unsatisfactory, alternatives are examined for cost correction or the project is terminated.

With the presently established procurement policies, DoD follows a similar process for system development and acquisition. Before each funding milestone, a proposed major system is subjected to several stringent reviews by the military department, the Defense Systems Acquisition Review Council (DSARC), the Office of Management and Budget (OMB), and Congress. (57:7) The decision for continual development requires satisfactory findings as to expected system performance and projected system costs. Consequently, the total costs of a program must be commensurate with performance and must fall within budgetary constraints. This may require tradeoffs in system performance and schedule. The strategy requires that viable alternatives be maintained until such time as the system selected for deployment has demonstrated the required performance and supportability within cost restraints. (17)

This concept of procuring systems within a cost constraint has been given various titles. These include design-to-cost, design-to-price, cost-to-produce, and design-to-cost-to-produce. For simplicity, this study will refer to the concept as design-to-cost.

Since its implementation by DoD, design-to-cost has been viewed in three different ways. (30:3-6) Various members of DoD have focused on the concept from the point of view of (1) a total force structure, (2) the life cycle of a weapon system, and (3) production of system hardware.

The first view of design-to-cost is a broad concept which is concerned with achieving a viable total force structure within foreseeable budget limitations. DoD officials state that if superior systems prove too costly, the military may be forced to procure more of the individually less capable systems. This approach, therefore, focuses on DoD's ability to balance system quality and quantity within fiscal constraints. The second view of the concept is one which emphasizes actions during the design phase of a weapon system to reduce its life cycle costs. Hence, life cycle costs are a key design parameter. The third and most limited view of design-to-cost is concerned only with the production cost of system hardware. The projected system production cost is a principal design parameter which influences the continuation or termination of a program. (30:3-6)

As seen in DoD Directive 5000.1, "Acquisition of Major Defense Systems," the official DoD attitude appears to be the second viewpoint:

> Cost parameters shall be established which consider the cost of acquisition and ownership; discrete cost elements (e.g., unit production cost, operating and support cost) shall be translated into "design-to" requirements. System development shall be continuously evaluated against these requirements with the same rigor as that applied to technical requirements. Practical tradeoffs shall be made between system capability, cost and schedule.
>
> Logistic support shall also be considered as a principal design parameter with the magnitude, scope and level of this effort in keeping with the program phase. Early development effort will consider only those parameters that are truly necessary to basic defense system design, e.g., those logistic problems that have significant impact on system readiness, capability or cost. (56:4)

Thus, it can be seen that the official DoD position concerning the design-to-cost concept favors a life cycle cost approach.

Basic Elements of the Concept

Although DoD officially emphasizes the life cycle cost approach, use of the concept requires the establishment of a unit production cost which it can afford to pay for the quantities needed. (59:2) The unit production cost is a primary design parameter equal in importance to system performance parameters. The concept requires that cost be emphasized continuously in tradeoff decisions and that the contractor demonstrate his ability to achieve the cost target before award of the production contract. Use of the concept requires attention to four key elements. These include:

1. System cost target
2. System performance goals
3. Production plan
4. Feedback mechanism

Cost Target. Establishment of the cost target is probably the most crucial aspect of design-to-cost. In the conceptual phase of a system acquisition, the total future cost of a program depends on the technology required, the number of units required, monetary inflation, delays, changes in system performance characteristics, and numerous other cost factors. Although some of these factors can be estimated only imprecisely, cost estimation techniques are extremely important in the establishment of the initial target cost.

There are basically two ways in which cost estimates can be formulated. These are the industrial engineering approach (sometimes referred to as the "cost up" or "grass roots" approach) and the parametric costing approach. The industrial engineering approach requires that the proposed system be broken out into its various components and that individual estimates be formulated for each of the subsystems. This approach has been criticized, however, since its use has resulted in a history of costs in excess of original estimates. (57:ii) One reason for this has been a tendency for designers to be overly optimistic in their estimates. (33:4) But there are other factors for this cost growth which include: estimating errors, requirements changes, funding limitations, unanticipated economic changes, and program advocacy on the part of the contractor, the military department, or both. Further, early cost estimates of systems requiring complex technical innovation have frequently failed to visualize the immense amount of detail required in obtaining acceptable operating systems. (57:11)

For these reasons, DoD is currently attempting to formulate a data base for preparing parametric system cost estimates. The parametric approach attempts to arrive at a cost estimate through the use of planning factors derived from similar past developments. These various additive, multiplier, and power factors are applied to the performance parameters (e.g. weight, airspeed, thrust) of the proposed system to obtain its estimated cost. As the program moves from the conceptual phase to the development phase and system elements become more clearly defined, the initial estimates can be revised.

After the Secretary of Defense approves the DSARC request to enter full scale development (usually DSARC II), the target cost established by the previous cost estimating techniques becomes a firm requirement of the development contract. Future development effort, therefore, must be geared not only to meeting the desired performance characteristics but also to insuring a system which can be produced at or below the target cost. Once the system cost target is established, subordinate cost targets can be formulated for the various subsystems and components. Establishment of these targets proceeds along the lines of the work breakdown structure.

Performance Goals. The establishment of system and subsystem performance goals is another important factor in the use of the design-to-cost concept. Unlike some acquisition policies, however, performance is not the dominating characteristic for program evaluation. Though desired performance characteristics may be specified, the concept requires an ability to trade performance factors for greater cost savings consistent with some minimal levels of performance. It should be noted, however, that failure to meet the cost target or the minimal performance levels would require that the program be examined for possible alternatives or termination. Consequently, design-to-cost requires rigorous use of cost-benefit analysis. Increments in cost must be justified by the benefits derived in performance from proposed system or subsystem designs, materials, or production methods. These cost increments must be consistent with the overall cost target.

Production Plan. System design not only influences performance characteristics, reliability, and maintainability, but it also influences the type of production method to be used. In addition to system design, the number of units required plays a major role in determining the production process and, consequently, the unit production cost.

Design and the quantity required directly affect direct labor, direct material, and factory overhead. For example, designs requiring special tooling or "clean room" facilities will increase the manufacturer's overhead. Usually specialized equipment is more economical for large production runs whereas general purpose tooling is generally more cost effective for smaller runs. The variable and fixed costs associated with labor, material, and overhead will vary depending upon the processes required due to system design and the size of production runs.

The design-to-cost policy is to address both recurring and nonrecurring costs of production. Since it is frequently difficult to associate a proportion of the non-recurring cost with each subsystem or component, overhead can be treated as a separate "design-to" goal of the overall system or of the separate major subsystems. Experience curves can then be utilized to measure progress toward meeting the recurring cost targets of the system and its components. While the cost of units produced early in the production cycle will usually exceed the cost target, the average cost per unit will fall due to the experience curve phenomenon. Consequently, the establishment of the experience curve and the production plan are important factors in determining management's ability to measure progress toward meeting the cost target.

Feedback. As stated earlier, when the Secretary of Defense approves the DSARC request to enter full scale development, the unit production cost is established and becomes a firm requirement of the development contract. During development, it is essential to track the designs of those items comprising the significant cost elements of the system. Though these items are only a small part of the total system, they compose the greatest percentage of total system cost. This concept of the importance of the few is known as the Pareto Distribution. Historically, 20 percent of a system's components compose approximately 80 percent of its cost. (96)

By monitoring design progress of the major cost components and evaluating the effect of designs on production costs, it is possible to determine the need for redesign action to meet the design-to-cost goal. The illustration on the next page depicts an example of a system's projected production costs based upon an analysis of designs produced. The top portion of Figure 1 illustrates progress toward the unit production cost goal through successive design iterations and shows how the impact of early system designs can be extrapolated to reveal potential production cost overruns. The lower portion of Figure 1 shows the expenditure of development budget as design iterations and time progress. If the possibility of an overrun exists, alternate designs should be developed. These design iterations of the major cost items should occur early in the development phase of the system program. Otherwise, there may be insufficient development funds remaining to correct

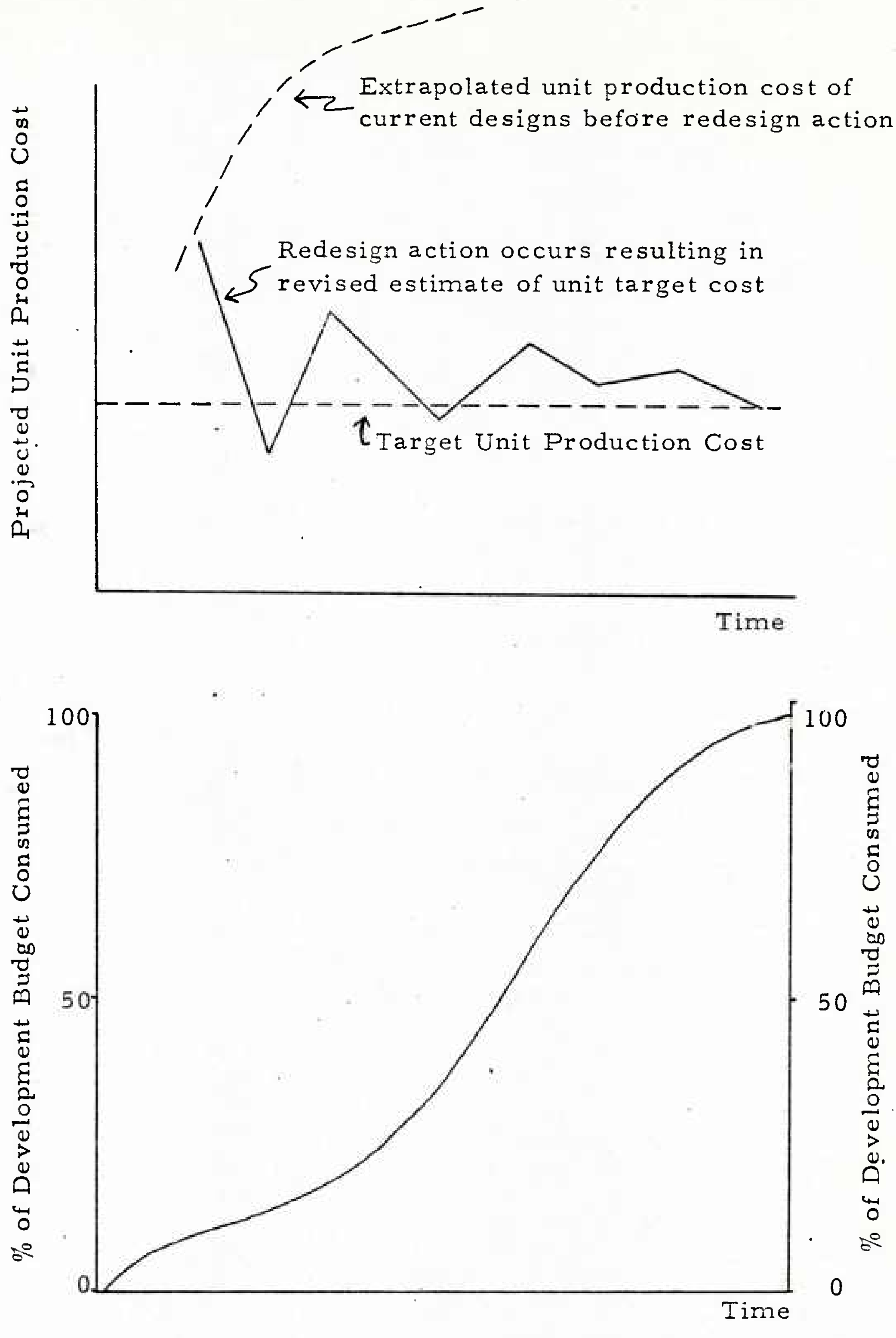

Fig. 1.--Projection of Production Costs and Effects of Redesign Actions in Relation to Development Funds Expended

Source: R. L. Bidwell and R. D. Gilbert.

designs which could cause excessive production costs. Thus, early design review will usually prevent sunk costs from consuming a major portion of the development budget. (8:6) Further, the early review of designs is important since system design will ultimately influence not only cost, but also performance, reliability, and maintainability.

Having presented a brief discussion to familiarize the reader with the development and basic elements of the design-to-cost concept, this chapter will conclude with an outline of the objectives and organization of this study.

Organization of Study

Scope

As noted earlier, design-to-cost has been considered from three different views: a force structure view, a life cycle cost view, and a production hardware view. The latter two are similar in that they concentrate on individual acquisition programs. As with any study, the authors found that time constraints forced them to limit their area of study. Therefore, this study will examine the impact of design-to-cost on individual weapon system acquisitions. More specifically, it will focus on the concept's use in major system programs. Major system programs are defined in accordance with DoD Directive 5000.1. The directive

> ... applies to major programs, so designated by the Secretary of Defense/Deputy Secretary of Defense.... This designation shall consider (1) dollar value (programs which have an estimated RDT&E cost in excess of 50 million dollars, or an

estimated Production cost in excess of 200 million dollars); (2) national urgency; (3) recommendations by DoD Component Heads or Office of Secretary of Defense (OSD) officials. (56:1)

Objectives

The design-to-cost concept is relatively new to DoD. At present there appears to be confusion as to the meaning of the concept and as to how it should be implemented. Therefore, the first objective of this study is to determine the concept's definition as applied in various system programs and to examine how the concept is being implemented in those programs. Although design-to-cost has been viewed as the antithesis of total package procurement, it has also been criticized as simply another name for the former procurement policy. Consequently, the second objective of this study will be to examine the differences and similarities of the two concepts and determine whether design-to-cost will alleviate the deficiencies of the total package concept. Finally, this study will suggest several areas for further consideration for the successful use of the design-to-cost concept.

Research Questions

Several research questions will be answered to achieve these objectives. The questions are as follows:

Research Question #1. What is the current status of design-to-cost implementation?

Research Question #2. Does the design-to-cost concept alleviate the deficiencies encountered in total package procurement?

Research Question #3. How can the use of the design-to-cost concept be improved?

Methodology

Information for this thesis was collected in two primary ways. Extensive research of available literature and written sources was undertaken. At the same time, interviews were conducted with DoD managers and military system program office personnel involved in the weapon system acquisition process. Both of these activities took place primarily at Wright-Patterson AFB, Ohio, and in the Washington, D.C. area.

Research. The preliminary research of books, theses, periodicals, and other special reports and documents was done primarily in the Wright-Patterson AFB libraries. Contracts for major systems being designed-to-cost were obtained from the Army Materiel Command, program offices of the Aeronautical Systems Division (ASD) of the Air Force Systems Command, and DoD offices. Handbooks, studies, and other literature were requested from various individuals and institutions that were working in closely related areas or had an interest in the topic. Although there had been much written on the weapon systems acquisition process in general, the authors soon found out there was little written material dealing specifically with the intended topic of this thesis.

Interviews. In order to seek out the unwritten details concerning DoD implementation of design-to-cost, interviews were conducted with researchers, educators, systems analysts, industrial engineers, procurement managers, and system program managers who had experience or knowledge in the area of design-to-cost.

The majority of these interviews were conducted at the program offices of the Aeronautical Systems Division at Wright-Patterson AFB, Ohio, since these offices were implementing design-to-cost in their programs and they were conveniently located near the authors. Other interviews were conducted at Headquarters U.S. Air Force, Headquarters U.S. Army, the Navy Department, various offices within the Department of Defense, and several independent research organizations. The basic interview guide used is shown as Appendix A.

Quantitative Data. The broad subject area of procurement management frequently does not lend itself easily to precise numerical evaluation. Specifically, the newness of the design-to-cost concept in DoD acquisitions prevented the authors in making a quantitative evaluation of the success of the concept. Therefore, a great deal of evaluation was done qualitatively.

Summary

The remainder of this study will attempt to answer the three research questions. Specifically, Chapter II, in answering the first research question, will analyze the current status of design-to-cost implementation. Chapter III will compare and contrast total package procurement with design-to-cost to answer the second research question, "Does the design-to-cost concept alleviate the deficiencies encountered in total package procurement?" Finally, Chapter IV will present some considerations for more effective use of the concept.

CHAPTER II

WHAT IS THE CURRENT STATUS OF DESIGN-TO-COST IMPLEMENTATION?

The purpose of this portion of the study was to examine the extent to which the design-to-cost (DTC) concept has been implemented in DoD acquisitions. All of the services have issued memoranda indicating that the concept is to be used in future system acquisitions. The Army, first to extensively examine the use of the concept, has prepared a handbook to guide program managers in the implementation of design-to-cost in system contracts. Though the Air Force has limited instruction concerning use of DTC, it has taken action to implement the concept in several existing system development programs and development programs just initiated. The Navy also has implemented the concept in some of its development programs even though information concerning its use has been extremely scarce. Recently, however, the Deputy Chief of Naval Material (Procurement and Production), Naval Material Command, issued a memorandum concerning the concept's implementation in future system procurements. It stated the concept would be used wherever appropriate to insure that cost is a principal design parameter. (12:2) In addition, the Office of the Deputy Secretary of Defense (Production Engineering and Material Acquisition) is preparing a handbook to give the military services further guidance in the implementation of the concept. (78)

In examining the extent to which design-to-cost is being implemented in current acquisitions, the authors have interviewed personnel in several system program offices and examined several development contracts issued by both the Army and Air Force. Since the authors are Air Force officers and since they are stationed near the Aeronautical Systems Division (ASD) of Air Force Systems Command, they have focused their attention primarily on the concept's implementation in Air Force programs monitored by ASD.

Three Conclusions

From their examination of these programs and contracts, the authors have arrived at several conclusions concerning the implementation of design-to-cost in DoD acquisitions. These conclusions can be grouped into the following three areas:

1. Definition of design-to-cost
2. Performance--cost tradeoffs
3. Contractual implementation

Definition of Design-to-Cost

The intent of DoD Directive 5000.1 is to establish cost parameters for systems which consider both the cost of acquisition and ownership. That is, the discrete elements of production cost, operating cost, and support cost are to be expressed in terms of "design to" requirements. The program office interviews and the review of the various contracts revealed ambiguity as to what element of cost should be "designed to" in implementation of the concept. The consensus is that the cost element of design-to-cost is an established unit production cost figure. This cost element does not include the operational or support cost elements of the weapon system as envisioned by DoD Directive 5000.1.

Four reasons can be given for establishing the unit production cost as the cost element in design-to-cost. First, the cost goals or targets established by DoD for weapon systems are in terms of unit production costs rather than life cycle costs or operational and support costs. Secondly, the literature concerning the concept defines cost as the "intended unit cost to acquire production items of specified performance." (58:2) Thirdly, DoD, the services, the program offices and the contractors can quantify the costs of production with greater certainty than they can quantify the costs of operation and support. Fourthly, DoD sells new programs to Congress, not on the basis of operational and support costs, but on the basis of the costs of research and development and unit production costs. Though there is a consensus concerning unit production cost as the "design-to" cost, there appears to be no general agreement as to what cost elements should be included in the production cost target since program offices define production cost differently. Some programs include recurring costs, non-recurring costs, and contractor profit in the unit target. Others exclude the profit portion from the target. Still other programs consider the unit target as consisting of only the recurring production costs. Further, there is no consensus as to how operational and support costs should be expressed in "design-to" terms.

Performance-Cost Tradeoffs

The second area concerning the implementation of the concept concerns performance-cost tradeoffs. One of the major characteristics of the programs implementing design-to-cost is the lack of stringent requirements concerning system performance. Most performance requirements are expressed in terms of goals. Although cost is considered a goal in addition to performance characteristics, it is, as one program director stated, "a goal more equal than the others." (89). Though system program personnel are careful to distinguish between a cost goal and a cost target, the difference is only a matter of semantics. It is evident that the goal constitutes an upper bound beyond which cost will not be allowed to fluctuate. Contractors are permitted to tradeoff cost against performance only up to the point that the cost constraint is not violated. Or, as is often the case, the contractor must tradeoff performance to meet the cost target. Thus the performance requirements are goals; the cost is a fixed requirement. This attitude toward cost and performance characteristics can best be seen in the comments of Lieutenant General James T. Stewart, ASD Commander, concerning contractor proposals for the Advanced Medium Short Takeoff and Landing Transport (AMST):

> We want each of you to pick what you think is the best combination (of performance characteristics) and define your concept of an aircraft which might be produced for somewhere near $5 million a copy by the 300th article. (2:Atch 1:4)

Contractual Implementation

A third area of general observations concerns the inclusion of design-to-cost in validation and full scale development contracts. All of the contracts examined can be characterized as cost-plus contracts. Several of the development contracts (e.g., B-1 RFS/ECM, UTTAS, SAM-D) provided for adjustments in the contractor's fee on a subsequent production contract depending on his success in achieving the production cost objective. However, there is no common method for implementing design-to-cost contractually. The contractual implementation of the concept ranges from incentive provisions to cost sharing provisions to award fee provisions. At this point in time it appears that no one best method can be identified for design-to-cost implementation nor that a particular method is even desirable. The method for the concept's implementation depends upon the system and or subsystem under development, the desired advances in system or component state-of-the-art, the ability to tradeoff performance requirements, and the degree of competition present in development.

Analysis of Individual Contract DTC Features

To support these three general observations concerning the current status of design-to-cost implementation, a brief analysis of key features of several weapon systems contracts that pertain to design-to-cost is provided. These key features include what costs are considered as the design to-costs and how the design-to-cost provisions are written into the contracts. In order that the reader will be familiar with the weapon system, a brief description of the system is also provided. The contracts analyzed below include the Advanced Medium Short Takeoff and Landing Transport (AMST), the Subsonic Cruise Armed Decoy (SCAD), the A-10A Close Air Support Aircraft, the B-1 Radio Frequency Surveillance/Electronic Countermeasures Subsystem, the Utility Tactical Transport Aircraft System (UTTAS), and the SAM-D Air Defense Missile System.

Advanced Medium STOL Transport

The Advanced Medium STOL (Short Takeoff and Landing) Transport Prototype is a feasibility demonstration of a low cost, austere field capable, medium STOL transport aircraft. It is one of several acquisitions in the Air Force Advanced Prototype Program. The program is designed to provide prototype hardware for Air Force test and evaluation of design, technology, and military usefulness in support of anticipated military needs. The objectives of the program are to explore the advantages of emerging technology, reduce the risks and uncertainties of full-scale development/production programs, and provide DoD with a variety of options that are readily available for application to military hardware needs. However, award of a prototype contract implies no commitment on the part of the Air Force toward future prototype, engineering development and/or production programs.

Specifically, it is significant to note that two of the four project objectives of the Advanced Medium STOL Transport (AMST) prototype concern the importance of acquisition costs. These two objectives are (1) to "provide a low cost development option for modernization of the tactical airlift force," and (2) to "obtain visibility on costs associated with short field performance." (1:Atch A:1)

In the request for proposal (RFP) for development of the AMST prototype, Lieutenant General Stewart stated: "It is our objective that any prototype proposed be consistent with a future production model which could be procured for a maximum of $5 million in FY 72 dollars." (1:1) The $5 million per production aircraft was defined as the flyaway cost of the 300th production unit that might evolve from any further development of the prototype design. Flyaway cost included *recurring cost only*, including government furnished aerospace equipment/government furnished equipment (GFAE/GFE). In stressing the requirement to not exceed the design-to-cost of $5 million, performance and design characteristics of the AMST were not stated as firm requirements but only as "goals." In addition, the potential contractors were instructed to perform tradeoff analyses among runway length, runway quality, payload, box size and range--the basic STOL mission--in order to achieve the production cost objective. (1:Atch 2:1)

The RFP was submitted to defense contractors on 24 January 1972. On 8 February 1972, General Stewart conducted a contractors' briefing to provide further guidance on the desired tradeoff analyses. He stated that the Air Force has a "need for a transport aircraft capable of hauling a decent-sized load into and out of fairly small, unimproved airfields. But, not at any price." (2:Atch 1:1) He further stated that in order to meet the cost objective, the Air Force has made a concerted effort not to design the aircraft. It has only "provided goals, not specifications." (2:Atch 1:2) If, in designing an aircraft toward the goals described in the statement of work, the estimated unit flyaway cost exceeds $5 million for the 300th unit, then the contractor should perform "a series of cost-sensitivity analyses, varying one parameter at a time toward a lower flyaway production unit cost. You [the contractor] should analyze each parameter noted in the RFP, plus any others you believe have a sizable cost impact." (2:Atch 1:3)

On 11 November 1972, prototype development contracts were awarded to the McDonnell Douglas Corporation and the Boeing Company. The contracts are cost reimbursement types with a maximum obligation to the government. Each contractor is to build two prototype aircraft. The prototype contracts provide a maximum of $96,219,457 for

Boeing and $86,112,230 for McDonnell Douglas. The Boeing contract is a cost plus fixed fee. The McDonnell Douglas contract is structured on a cost sharing basis with the government paying 72.1 percent of all allowable costs. However, in each case, the maximum obligation to the government is not to exceed the above amounts.

The Boeing prototype, the YC-14, is a high-wing, two-engine aircraft employing upper surface blowing to produce lift. The McDonnell Douglas YC-15 is a high-wing, T-tail aircraft designed with externally blown flaps and other high-lift technology devices. The total estimated cost for the performance of the Boeing contract is $89,924,726, while the total estimated cost for the McDonnell Douglas contract is $119,410,230. Both contracts state the importance of the unit production cost as defined below in determining if further development or production is pursued. The production aircraft cost goal is stated as

> $5.0 million flyaway cost (January 1972 dollars) for the 300th production article in a reasonably paced production program. This goal is of fundamental importance in the design of the prototype aircraft. Potential production cost will be a major factor in determining if this program is pursued beyond the prototype phase. (50:2-3)

The only significant design requirement stated in the contracts concerns the size of the cargo compartment. All other design and performance characteristics, such as payload, speed, combat radius, and runway length, are stated only as <u>goals</u>. For example, the speed goal is simply stated as "normal turbojet or turbofan powered transport cruise speeds." Thus both contractors are given flexibility in meeting the design-to-unit production cost.

Subsonic Cruise Armed Decoy Missile

The Subsonic Cruise Armed Decoy (SCAD) missile is being designed to counterbalance the increasing number of Soviet high-performance interceptors which eventually may have a look-down, shoot down capability. The SCAD's principal mission is to confuse, dilute, and, whenever possible, saturate the enemy's area defense system. It will be launched from B-52s and will normally operate in a preprogrammed manner to simulate mission profiles of the B-52. The SCAD development effort is based on an associate contractor structure with the program office responsible for systems integration. The Boeing Company is responsible for the airframe and the air vehicle; Philco-Ford for the decoy subsystem; Litton Systems, Inc., for guidance/control; and Teledyne CAE and Williams Research Corporation for propulsion.

Design-to-cost goals were not included in the SCAD system contracts originally. Supplemental agreements were negotiated with each SCAD segment contractor to introduce the concept. When the SCAD program office initially attempted to amend the contracts to include design-to-cost goals, the price for design-to-cost implementation reported by each segment contractor ranged from $275,000 to $2,462,382, for a total program cost increase of approximately $5 million. This price was considered prohibitive. The SCAD program office then attempted to implement no cost supplemental agreements to the SCAD segment contracts which would accomplish these three objectives: (1) recognize a design-to-cost goal for recurring production costs in each contract; (2) provide that the design-to-cost goal be addressed at the monthly Segment Status Review and be analyzed at key milestones in the program; and (3) amend the statement of work so that any future engineering change proposals (ECP) would include the net change in the design-to-cost goal resulting from the ECP. Design-to-cost supplemental agreements were negotiated with all SCAD segment contractors. However, one segment contractor, Boeing, refused to amend the statement of work to include the impact of engineering change proposals on the design-to-cost goal. Further, Litton and Teledyne agreed to indicate the impact of an ECP on the design-to-cost goal only if the goal were changed by 10 percent or more.

The SCAD design-to-cost goals were for *recurring production costs only, excluding such elements as general and administrative expenses, tooling costs, sustaining engineering expenses and profit.* (96)

The following is an extract from the supplemental agreement negotiated between the government and Litton Systems, Inc. It is presented to provide an example of the language used in establishing the design-to-cost goal in a SCAD segment contract:

> The contractor hereby agrees that the FY 75-79 Design-to-Cost goal for the SCAD Navigation/Guidance segment is $50,100 in then year dollars based on a total of 1500 units calculated at a monthly delivery rate of 35 units. The Design-to-Cost goal includes all recurring costs associated with the unit production of the SCAD Navigation/Guidance segment and the aforementioned goal is based upon prior delivery of thirty-five (35) RDT&E Navigation/Guidance segments with initiation of production delivery immediately thereafter. The Design-to-Cost goal shall be addressed at each Segment Status Review (SSR) and reviewed if variance of approximately 10% in the Design-to-Cost goal is projected. The Design-to-Cost goal shall be reviewed and analyzed at Critical Design Review, Delivery of System #1, and Completion of Qualification Testing. (51:1)

All segment contractors expressed concern over the fact that they were agreeing to a no cost change and an additional reporting data point. However, the supplemental agreements negotiated are inherently weak, since they reflect only goals toward which the contractor agrees to work with no contractual incentives or penalties. In addition, the contractors will be given the opportunity to amend the goals at certain program milestones. The significance of the supplemental agreements lies in the fact that a production objective was clearly established and a mechanism to review production costs was provided, while expending no additional funds in doing so.

A-10A Close Air Support Aircraft

The A-10A is a close air support aircraft being developed by Fairchild Industries, Inc. A twin tailed, single place aircraft with drooped wing-tips, it is powered by two General Electric TF34 turbofan engines of over 9000 pounds thrust each. The contract for the full scale development of the A-10A was awarded to Fairchild Industries, Inc. after a prototype competition between Fairchild and Northrop. The prime objective of the full scale development phase is to design a system which will have an average unit production flyaway cost of $1.5 million (1970 constant dollars) based on a total of 600 aircraft.

The unit production flyaway cost is defined as the *sum of all recurring and non-recurring (excluding RDT&E) costs* necessary to produce a complete aircraft. Recurring costs include the costs of the airframe, propulsion units, electronics, armament, GFAE/CFE (government furnished aerospace equipment/contractor furnished equipment), and engineering change orders (ECO) of a recurring nature necessary to meet system specifications. Non-recurring costs include those costs associated with the necessary tooling and production engineering required to achieve a specific production rate, the applicable costs associated with system engineering and program management, and those ECO costs classified as non-recurring. (47:57)

The contract between the Air Force and Fairchild for the full-scale development of the A-10A is a cost-plus-incentive fee with an added award fee provision. The incentive fee is based on the contractor's ability to perform the full-scale development effort at a target cost of $147.5 million. The contractor's target fee is $11.8 million. The government and contractor share the difference between actual and target cost according to a 70/30 sharing ratio respectively. The contractor can earn a maximum fee of 15% of contract cost. The payment of the award fee is based upon the contractor's success in minimizing adverse logistics effects. The maximum award fee payable is $2.9 million.

Though the attainment of a unit production cost of $1.5 million is stipulated in the development contract, there is no applicable incentive or award fee provision in the A-10A contract. The contractor might be motivated to maximize the incentive fee by curtailing development cost. In doing so, he could fail to expend the funds for necessary cost tradeoff analysis and development which will insure that the system can be produced for $1.5 million. The system program office reasons, however, that should the contractor not be able to demonstrate a viable system for the dollar constrained amount, the DoD will, in all probability, terminate the program. This, then, provides the contractor the necessary motivation to meet the established unit production cost.

B-1 Radio Frequency Surveillance/Electronic Countermeasures Subsystem

The B-1 advanced manned strategic bomber is designed to replace the B-52 and counter the Soviet threat of the 1980's. The radio frequency surveillance/electronic countermeasures (RFS/ECM) subsystem is one of the major elements of the aircraft. Its purpose is to enable the B-1 to penetrate the enemy's defense network.

The first B-1 contracts initially awarded were for the airframe and engine development. In 1970, Rockwell International was awarded the airframe development contract while the Air Force awarded the engine development contract to General Electric. In 1972, the contracts for the initial development phase of the RFS/ECM subsystem were awarded.

The development program for the RFS/ECM subsystem consists of two phases. The first phase is a competitive definition and risk reduction effort on the part of two independent contractors, the Raytheon Company and the AIL Division of Cutler Hammer. During the first phase, each contractor has prepared a proposal for the second phase, full scale system development. Next one contractor will be selected for the continued development effort. A principal design parameter of the initial competitive development phase has been that the average unit production price for 241 units must not exceed \$1.4 million (1972 constant dollars).

Instructions in preparation for the second phase of the development effort emphasize the basic tenets of the design-to-cost philosophy. Only key performance parameters are specified in the instructions for contractor proposals, and the contractors have the flexibility to establish others. The competing contractors are required to propose a system capability which will meet the \$1.4 million unit production cost constraint. During full scale development, the winning contractor's proposal will serve as the baseline system, and his future development efforts will be directed at designing and fabricating a system that meets the specified capability within the cost limitation.

Procurement personnel for the RFS/ECM subsystem determined that the most appropriate method for implementing design-to-cost was a dual incentive contract (CPIF/IF). Cost plus incentive fee (CPIF) contracts, which are used for most system development efforts, were first considered. However, this approach was rejected since the contractor may be penalized for incurring additional development costs associated with design iterations aimed at decreasing unit production costs. Procurement personnel considered retaining two contractors throughout the development phase, but determined that this would not only be too expensive but would also present management and interface difficulties due to the interdependency of the ECM design with other B-1 development activities. A production option was considered infeasible due to the lack of design specifications. Value engineering provisions were rejected, since the contractor is neither obligated to reduce costs nor is he penalized for not reducing them.

In developing the structure of the ECM development contract, procurement personnel have two objectives in mind: (1) motivating the contractor to achieve the unit production cost goal and (2) inducing the contractor to limit development cost growth. To achieve these seemingly paradoxical objectives, the development contract for the ECM will be structured as a dual incentive fee contract. The contract will contain a modified cost plus incentive fee provision for the cost of the development program and a performance incentive provision based on the contractor's ability to meet and/or improve on the unit production cost goal.

In proposal instructions released to the contractors, several modifications to the usual CPIF contract have been made. The maximum fee is limited to six percent of the program development target cost. (This target is tentative since it will subsequently be negotiated with the contractor.) The fee will be attained for any cost outcome up to target. This is intended to encourage the contractor to incur higher development costs to obtain an improved system which will meet the unit production cost goal. Above the development cost target, the contractor shares in all expenditures. The government and the contractor share all development costs on an 85/15 sharing ratio respectively up to the point where the contractor's fee is zero. Beyond that point, the government and the contractor share all expenditures according to a 60/40 ratio respectively. (See Figure 2.) Consequently, the contract would become a cost sharing arrangement for a substantial overrun.

In addition to the CPIF arrangement discussed above, the contract will include a design-to-cost incentive fee based on the contractor's ability to design the RFS/ECM subsystem within the unit production cost constraint. The amount of fee paid will be directly related to the amount that the average subsystem price is less than $1.4 million. This determination will be in accordance with the conditions of the development contract after the negotiation of the initial production contract.

Besides the incentive fees that the contractor may earn on the

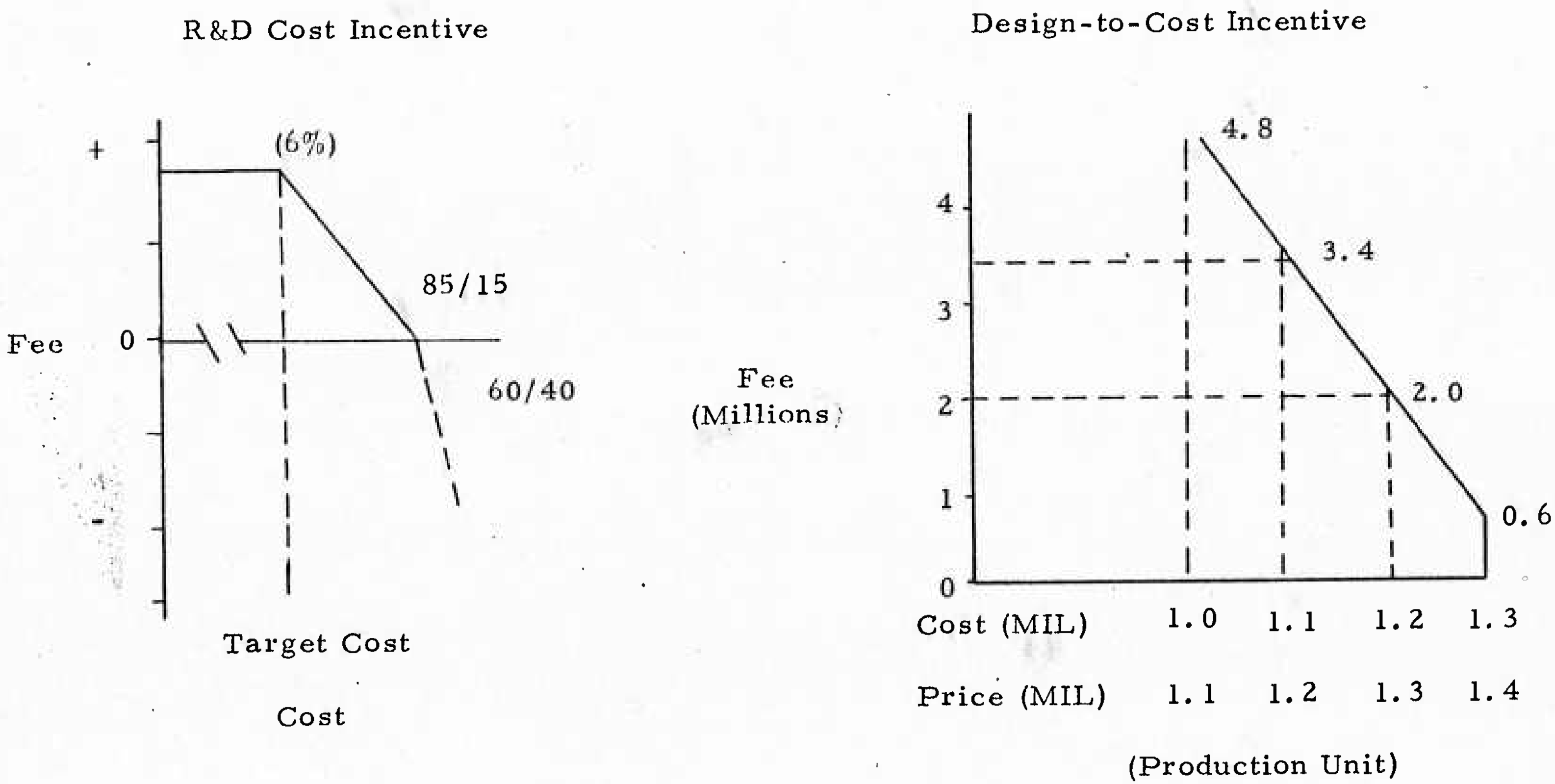

Fig. 2.--Dual Incentive CPIF/IF (Research and Development Contract)

development contract, the percent of target profit on the initial production contract will be directly related to the amount that the negotiated unit price is below the $1.4 million target. Consequently, the contractor will earn a higher profit on the production contract for producing a less expensive subsystem.

The design-to-cost target of $1.4 million includes only those costs and profit related to the "fly-away" RFS/ECM subsystem, including tooling, direct and indirect manufacturing and engineering, and sustaining engineering. Specifically excluded from the DTC target are spares, training, and aerospace ground equipment.

The development contract sets forth specific parameters for maintainability and reliability. However, no maintainability or reliability demonstration is required during the development program. Instead, program personnel intend to implement a failure-free warranty in the initial production contract. During the second phase of the development program, the contractor is to estimate the cost of such a warranty and will revise the estimate as necessary. The cost of the failure-free warranty is specifically excluded from the unit production cost.

Utility Tactical Transport Aircraft System

The Utility Tactical Transport Aircraft System (UTTAS) is being designed to replace the present Bell UH-1 series helicopters as the Army's primary small unit transportation system. Boeing Vertol and Sikorsky have been selected to develop prototypes--the YUH-61 and YUH-60 respectively--for a competitive flyoff. The major goal of the development program is to design a helicopter with significantly lower operational and maintenance costs than existing systems. Higher reliability is also a principal goal.

The stated objective of the UTTAS contract is the successful development of a transport system that can be produced at the lowest possible production and life cycle cost, thus adhering to the requirements of DoD Directive 5000.1. However, the design-to-cost provisions of the contract deal only with unit production costs. The UTTAS airframe unit production cost objective has been established "at an average recurring airframe cost of $600,000 or less (constant FY 1972 dollars)." (53:Atch A:1)

Recurring cost has been defined as including *recurring engineering direct labor and applicable engineering overhead, manufacturing direct labor and applicable manufacturing overhead, general and administrative overhead, material and profit on recurring costs only associated with production, and the cost for installation of government furnished equipment such as engines, avionics, and weapons*. The design to production cost excludes such non-recurring costs as tooling, non-recurring engineering, and total cost of kits, GSE, GFE, and data.

In order to provide an incentive for the contractor to meet the design to average airframe cost, the fee on the UTTAS prototype contract will be adjusted within a prescribed range depending on the success of the contractor in meeting the cost objective. If the average airframe cost negotiated is less than the design-to-cost objective of $600,000, then the contractor's final negotiated fee will be increased by 15 percent of the difference between the average production cost and the cost objective (multiplied by the total number of aircraft to be procured on the first production contract). If the negotiated cost is less than $550,000, 20 percent will be used in the computation instead of 15 percent. However, if the average cost negotiated exceeds the production cost objective of $600,000, then the contractor's final negotiated fee will be reduced by 15 percent of the difference between the average airframe production cost and the cost objective (multiplied by the total number of aircraft to be procured on the first production contract).

SAM-D Missile System

The SAM-D battlefield air defense missile system is designed to provide the Army with a mobile air defense missile system for use with larger Army units, eventually replacing the Nike series and the Hawk missiles.

The Raytheon Company was selected as the SAM-D Weapon System Engineering Development Contractor. Unit production price goals were stated in the Raytheon contract for the four major subsystems of the SAM-D System--missile, radar group, weapon control group, and launcher group. The cost goals were based on hardware configurations established, use of 1972 constant dollars, and the production schedules and cost relationships negotiated. In addition, the contract also required that price goals for major components of these four subsystems be established and included in development specifications.

The production unit price used in the Raytheon contract included all costs "normally included in the contractor's hardware production contracts" (54:23) such as all labor, including fabrication, assembly, test and inspection, manufacturing engineering, and production control; all material, including purchased parts, raw materials, and subcontracts; all burdens including labor and material overhead, maintenance and modification of special tooling and test equipment; and profit and fee.

An award fee not to exceed $5,068,857 was included in the contract. Significantly, one of the criterion used in evaluating the contractor's performance in determining award of the fee was "management of effort toward achieving the production unit price objectives." (54:6a)

In order to evaluate life cycle cost considerations of production hardware, in the Raytheon contract the government stated its intention to contract with a System Engineering Cost Reduction Assistance Contractor (SECRAC). The SECRAC would serve in an advisory capacity to the government in identifying and recommending means for reducing production hardware cost within the overall life cycle cost considerations. (54:33)

Finally, if Raytheon is selected to receive the first SAM-D production contract, a reward/penalty feature will be included by which there will be an increase of 15 percent in earned fees if the final cost of the production contract is less than the target cost. Conversely, there will be a 25 percent decrease in earned fees if the final cost of the production contract is more than the target cost. If the contractor is within a ten percent range of the target cost, no such increment or decrement in fee will occur. However, within this ten percent range, all costs or savings will be shared on a 65/35 ratio. (54:1a)

Summary

In examining the programs currently attempting to implement design-to-cost, it is apparent that ambiguity exists as to what cost elements constitute the cost to be "designed to." Though there is general agreement that design-to-cost refers to unit production costs, there is no consensus as to the cost elements that should be considered in establishing a unit production cost goal. Some contracts include only recurring production costs while others include recurring and non-recurring production costs such as plant overhead. Still others provide an allowance for profit in the unit production cost goal. In addition, the establishment of a unit cost goal based on production costs is not totally consistent with the objectives of DoD Directive 5000.1. None of the program offices have attempted to express operational or support costs in design-to terms. The primary reason for this has been due to the nebulous characteristic of the operational and support aspects of the system during the development effort. Clearly, if design-to-cost is to be a viable management tool for evaluating program performance and alternatives, then a common definition of cost will be required. Further, a method for assessing the operational and support aspects of proposed designs needs to be integrated into the overall concept.

It is also evident that use of the concept will require tradeoffs in system performance to meet established cost goals. At present there is no common method for implementing the concept in development contracts. The method for the concept's implementation depends upon the system under development, the desired advances in state-of-the-art technology, the ability to tradeoff performance requirements, and the degree of competition prevalent during development.

Some of the development contracts examined provide for increased contractor fee on a subsequent production contract if the contractor can produce the system at a unit production cost lower than the cost objective. It is not clear at this time how the contractor would be rewarded for achieving a lower unit production cost if the system, for some reason, should not be approved for production. This poses a dilemma for the contractor, particularly when he may have to exceed the target development cost (and thus share in or assume all further development costs) in order to achieve the production cost objective.

Having examined the concept's implementation in various programs, this study will now address the second research question, "Does design-to-cost alleviate the deficiencies encountered in total package procurement?"

CHAPTER III

DOES DESIGN-TO-COST ALLEVIATE THE DEFICIENCIES ENCOUNTERED IN TOTAL PACKAGE PROCUREMENT?

The design-to-cost concept has been initiated as part of the incremental decision strategy adopted by DoD and the services to replace the total package procurement concept. However, critics of the DTC concept have stated that it is no different than total package procurement. Hence, the purpose of this portion of the study is two-fold. It is first necessary to comparatively analyze the differences and similarities of design-to-cost and total package procurement. Then it may be possible to predict if design-to-cost will alleviate the deficiencies encountered in total package procurement. Before the two concepts are compared, a description of total package procurement is necessary.

Total Package Procurement

Total package procurement (TPP) was a method of integrating into a single contract all anticipated development, production, and support needed to introduce a system into the inventory and sustain it throughout its operational life. Thus a system would be procured as one total package with price, performance and schedule commitments written into one contract. (44:1)

TPP Implementation

Before the total package procurement concept was initiated, weapon system contracting was almost exclusively based on design or technical competition. Although acquisition of a major system involved negotiation of a separate development contract, a separate initial production contract, separate follow-on production contracts, and contracts for training, spares, support systems and other operational requirements, competition was usually limited to the developmental phase. Contractors who had received development contracts were at an advantage when subsequent production contracts were to be awarded. Selection of a production contractor other than the one responsible for development required extra time and expense. Thus further negotiations were usually conducted in a sole source environment and the competitive atmosphere was lost. Since the development effort comprised only 20 percent of the total program cost, the remaining 80 percent had to be negotiated in a non-competitive atmosphere. This gave rise to "buying in" tactics where the price proposed on development contracts was not solely related to an efficient cost but also to the contractor's expectations about future sales. A primary aim of TPP was to associate a contractor's proposal with both development and production of a system so that the contractor could not buy into a program and then "get well" later in subsequent negotiations conducted in a sole source environment. (21:6-7)

At the same time as additional competition was being encouraged, a major effort was made to reduce the amount of contracting on a cost-reimbursement basis. Cost-plus-a-fixed-fee contracts were put under special pressure with incentive arrangements being strongly encouraged. (36:18-19)

<u>Expected Benefits</u>

The benefits that proponents of TPP expected from applying the concept included: (44:3-5)

1. TPP would require a tightening of design and configuration discipline on the part of the contractor. It would also require the government to be more specific in telling industry what it wanted. Thus the system would be better defined before substantial resources were allocated to it.

2. TPP would inhibit unrealistic "salesmanship" or "buy-in bidding." Thus DoD could choose between competing contractors based on binding commitments concerning the performance and price of the system.

3. The contractor would be motivated to design initially for economical production, reliability, and maintainability because of

commitments to cost and performance figures for production units before detail design began.

4. The contractor would be motivated to obtain supplies and services from the most efficient source.

5. Because of increased competition at program initiation, the need for subsequent competitive reprocurement of components would be decreased.

6. The winning contractor would be forced to be efficient because of commitments established in a competitive environment.

A RAND Corporation study on the effects of TPP on innovation and product quality in systems development pointed to the limitations of the concept. Specifically, it stated that TPP would have adverse effects where "the requirement is uncertain, the need is extremely urgent, the technology that must be used is unproven, and where the measures of system effectiveness are diffuse and qualitative." (21:26)

Cost-Effectiveness: The Criterion

Perhaps the best known application of the total package procurement concept is the procurement of the C-5A aircraft. The RFP stated that the C-5A contract would be awarded to the source whose cost and technical proposals demonstrated the greatest over-all cost effectiveness over a 10-year operating period. (36:25) Thus in using cost effectiveness as a criterion for source selection, total package procurement did not require that the lowest bidder be awarded the contract. Instead, awards were to be made on an integrated, meaningful basis considering performance and price commitments. (36:36)

Comparative Analysis

As has already been noted, design-to-cost is part of the overall DoD incremental acquisition strategy. In an effort to provide system programs with exercisable, viable alternatives, the strategy calls for Defense Systems Acquisition Review Council (DSARC) and service reviews throughout the life of the development program. Coupled with these reviews is the requirement for separate contracts for development and production. During the DSARC and service reviews, cost is given major consideration for program continuation and the ultimate decision to enter a production contract. Though system performance goals are specified, DTC requires tradeoffs in performance and schedule to meet the cost objective consistent with minimal performance requirements.

Since design-to-cost attempts to control unit production costs at the beginning of a program, many persons have reacted that this is a step back to total package procurement. (29:22) However, Dr. John S. Foster, Jr., Director of Defense Research and Engineering, has stated that "designing to a price is not, as some people have asserted, a move back toward total package procurement." (17) There are several differences between these two concepts. They include:

1. Decision strategy

2. Commitments versus goals

3. Cost effectiveness versus maximum performance under cost constraints

4. Program cancellation

Differences

Decision Strategy

The most significant difference between design-to-cost and total package procurement is that of decision strategy. In a single-point decision, the Department of Defense, in using the TPP concept, selected one contractor for the development, production, and support of a system with specific price, performance, and schedule commitments written into one contract. On the other hand, DTC utilizes an incremental decision-making strategy in which several production options are given the government, but most importantly, the development contract implies no commitment on the part of the Defense Department to any further contracts or programs. Dr. Foster, in comparing the decision strategy of the two concepts, stated:

> Total package procurement required one decision to develop and produce specified numbers of a system to specified performance, cost, and time limits. The new policies (DTC) emphasize incremental acquisition and early flexibility in design specifications. (18)

Commitments Versus Goals

Total package procurement required that specific price, performance and schedule commitments be written into a single contract. Such firm requirements greatly reduced the flexibility of the contractor in designing the system. Proponents of TPP realized that "commitments to operational performance of hardware are of little value in the absence of adequate testing." (44:14) Thus in attempting to meet performance commitments with major unknowns still in existence, cost or schedule commitments might be violated, requiring that the basic contract be reopened for negotiation.

However, design-to-cost emphasizes the use of tradeoffs in meeting the required unit production cost target. For example, the only significant design requirement for the AMST is the size of the cargo compartment. All other design and performance characteristics such as payload, speed, combat radius, and runway length, are stated only as goals, thus giving the contractors flexibility in meeting the design-to-unit production cost.

Cost Effectiveness Versus Maximum Performance Under Cost Constraints

As has already been stated, total package procurement used a criterion of cost effectiveness for source selection. The intent of TPP was to award the contract to the source whose cost and technical proposals demonstrated the greatest over-all cost effectiveness over a specified operating period. Therefore, awards were to be made considering both performance and price commitments.

On the other hand, a unit production cost ceiling is established for systems acquired under the design-to-cost concept. Given this cost constraint, the source whose technical proposal demonstrates the maximum performance will be awarded the contract.

Program Cancellation

Another major difference between the two concepts concerns action taken when program objectives are not met. The total package procurement concept emphasized conditions that inhibited contract changes and required the contractor to correct deficiencies in the system. (21:iii) Frequently, however, the price, performance, and schedule commitments established in a competitive environment were revised due to changes to drawings, designs, or specifications. The problem of such contract changes cannot be overlooked.

> The weakest points in the chain leading from competitively established initial contract commitments to final contract realizations are those situations in which the contract is reopened for negotiation during the course of the program and therefore on a sole source basis. (44:11)

However, proponents of DTC state that if the design-to-cost target cannot be met, the program will be cancelled. According to Dr. Foster: "In total package procurement, failures along the way resulted in desperate efforts to patch up a wrong initial decision. Failures under the design-to-cost approach will result in early termination." (17)

Similarities

Although Dr. Foster has stated that the two concepts of design-to-cost and total package procurement "are just about opposite," (18) there are several areas in which TPP and DTC are similar. These similarities can be grouped into six categories. They are:

1. Use of existing technology
2. Definition of design
3. Extent of required development time
4. Development of unit production cost
5. Extent of program competition
6. Choice of contractor

Use of Existing Technology

Proponents of total package procurement recognized that the concept could not be applied unless the technological building blocks of the system were well established. (44:5) Since the concept covered program development, production, and support efforts, its application was to be limited to programs whose performance parameters could be met with existing technology or to projects which required few increments in the existing state of the art. In a similar vein, proponents of design-to-cost recognize that it can have its greatest potential in system programs requiring few increments in existing technology. In highly sophisticated weapon systems with substantial unknowns and required increases in the state of the art, DTC could at best be applied on a component basis.

Definitized Design

Since in any development effort there are technological uncertainties, the total package concept recognized the need for a rigorous design effort to meet price and performance commitments before entering the production phase. (44:3) The DTC concept also requires rigorous design efforts in an attempt to arrive at a system configuration which meets the unit cost constraints and minimal performance specifications. This then becomes the baseline for determining the decision to enter production.

Extent of Required Development Time

Proponents of TPP recognized that the time required to perform adequate development work would have to be lengthened the greater the amount of technological uncertainty inherent in the system. This is also true of the DTC concept. The greater the amount of development time, the greater the ability to achieve a system which meets performance goals and cost constraints.

Development of Unit Production Cost

The TPP concept, as originally envisioned, provided for the establishment of a unit production cost early in the design effort similar to the present DTC concept. The purpose of the TPP unit target was to motivate the contractor to design initially for economical production consistent with reliability and maintainability commitments. A unit cost target is also established by DTC with the objective of preventing unnecessary system sophistication and excessive production costs. By establishing a unit production target, DTC proponents anticipate the development of simpler systems as a result of rigorous design analysis. Improved operational and support costs are expected as a by-product of these simpler designs. This subject will be addressed further in Chapter IV where life cycle costs are discussed.

Extent of Program Competition

TPP and DTC are also similar in respect to the extent of the program competition. TPP required that the contractors compete on the entire system project, i.e. development, production, and support. At the end of this competition, one contract was awarded covering the entire program. DTC, technically speaking, requires competition in selection of the contractor for the full scale development effort. It then requires the negotiation of a subsequent production contract. It is doubtful that a production contract would be awarded to anyone other than the firm responsible for full scale development since that firm would have the necessary technical knowledge and expertise. Further, few contractors would be willing to invest the necessary capital to conduct an independent military research and development effort in order to compete for later production contracts. (70) Consequently, though the contractors are technically competing only for the full scale development effort, they are realistically competing for the entire program. For example, Lieutenant General Stewart, ASD Commander, has stated that "the Fairchild-Northrop price comparison included the cost for development, test, and production, operation and support of the complete A-X program." (3:48)

Choice of Contractor

TPP and DTC are similar in one final aspect. Neither one requires the selection of the lowest cost proposal. In using TPP, the proposal was based on total program cost whereas with DTC it is based on full scale development cost. TPP awarded contracts to that source whose cost and technical proposals demonstrated the greatest over-all cost effectiveness for a specified time period. This did not necessarily mean the lowest cost proposal was awarded the contract, since it was possible to obtain greater over-all system performance from a source whose cost might be higher. DTC recognizes that to achieve lower production cost and support cost systems, it may be necessary to have increased development budgets. In turn, this may mean selecting a contractor whose development cost may be greater but who has a greater potential for achieving performance goals consistent with cost constraints. In the A-X competition, the Fairchild A-10 was selected over the Northrop A-9 even though the Air Force believed that the A-10 might "be $50,000-$100,000 (FY 70 dollars) per aircraft more expensive than the A-9" (3:44) and Northrop might have been able to meet the unit cost goal easier than Fairchild. Thus, it is apparent that neither concept requires that the lowest cost proposal be selected.

Summary

It is apparent that design-to-cost is similar to total package procurement in several areas. The differences are primarily attributable to the decision strategy employed by DoD and the services in weapon system acquisition. Total package procurement was a single point decision strategy covering an entire acquisition. At present DoD and the services require an incremental strategy requiring separate decisions for full scale development, production, and follow-on support. Further, TPP required fixed commitments to performance, schedule, and cost requirements whereas DTC requires commitment only to a cost requirement.

Does DTC Alleviate the Deficiencies of TPP?

In a 1966 pamphlet published by the Air Force, the application of total package procurement to the C-5A acquisition was called "an unqualified success." (44:26) However, hindsight has shown that this is not the case. The disrepute into which the total package concept has fallen is due largely to its use in this acquisition program. The DoD position on TPP is clear. DoD Directive 5000.1, "Acquisition of Major Defense Systems," specifies that major systems "will not be procured using the total package procurement concept." (56:5)

In examining whether design-to-cost alleviates the deficiencies encountered in TPP, it is necessary to concentrate on the deficiencies of the concept and not on the symptoms of those deficiencies or the misapplication of the concept. The deficiencies of TPP and its misapplication resulted in cost overruns, frequent engineering changes, and contractor "buy-ins." Although these were major problems, one cannot overlook the fact that the deficiencies were the basic cause. Total package procurement was deficient if any of the following three main characteristics existed: (1) uncertain mission requirements, (2) major technological uncertainties, and (3) urgent need. (21:26)

Uncertain or Changing Mission Requirements

Total package procurement included two important concepts. They were "vigorous contract definition activities and... conditions that inhibit contract changes." (21:ii) These two concepts were designed to eliminate or reduce as much as possible "buy-in" tactics in which a contractor submits an unrealistically low cost estimate and hopes to improve his poor financial situation by negotiating changes later in the program in a sole source environment. Reducing contract changes places a greater burden on the contract definition activities, since a "definition of a 'correct' configuration becomes of prime importance." (21:14)

Thus, for TPP to be successful, the mission of the system had to be defined precisely to avoid unnecessary contract changes. In addition, the desire to inhibit changes hindered adapting the program to new threats or technological possibilities. Further, the "growth potential," the ability to perform missions and use equipment not anticipated at the beginning of development, of systems procured under TPP was limited. This quality is often necessary, since it is difficult to anticipate all threats that may arise or the capabilities that may be permitted by new technological advances. The highly optimized B-58 is an example of a system with little growth potential. The Minuteman system, too, has limited growth potential, since the initial concept, as embodied in the missile and silo sizing, has limited changes in the missile's functional capabilities. (21:14-17) In addition, TPP proponents realized that the concept should be judiciously used if "certainty of system characteristics and requirements" was questionable. (44:33)

DTC and Mission Requirements

In designing a system to a cost constraint, DoD officials have stated, "Increased performance (i.e. capabilities) with its implicit higher costs" must be avoided. (42) Therefore, the first requirement in developing new systems will be the rigorous establishment of system functions. (95) This may require the design of systems for individual roles rather than multi-purpose roles as has been attempted in the past in an effort to avoid complex weapon systems and their inherent higher costs. (82)

As noted with total package procurement, the need to establish definitized functional requirements for weapon systems may limit their growth potential. For this reason, design-to-cost may be limited to system development where the threat is relatively unchanging. Where the threat that the system is designed to counter is uncertain or subject to change, DTC, as currently envisioned, will not necessarily be an improvement over total package procurement. Using DTC in developing a system to counter a changing threat can result in three possible actions. First, DoD can ignore the changed threat and continue to develop the system as proposed. Second, DoD can make necessary changes to the system to counter the different threat. This, however, may violate the cost ceiling originally established. Third, DoD can elect to terminate the program and investigate alternative systems to meet the changed threat. This, of course, will require increased expenditures and time during which the threat may again change.

Changing threats may require changes in system functional characteristics. This, in turn, may require changes in the unit production cost. Consequently, the design-to-cost concept, as it is currently viewed, would not be credible for system programs attempting to meet an uncertain threat.

Existing Technological Uncertainties

The total package procurement concept required that commitments to price, schedule, and performance be written into the contract. However, "commitments to operational performance of hardware are of little value in the absence of adequate testing." (44:14) Thus successful implementation of TPP was predicated on the requirement "that most significant technical advances associated with a program be made prior to the contract award." (21:iii) Proponents of TPP stressed the importance of the Advanced and Exploratory Development activities of the Department of Defense and the independent research and development activities of contractors.

Use of a "building block" approach was advocated in which advanced development programs established the feasibility of subsystems and components before full scale development was initiated. In the C-5A, significant technical advances were needed in the engine to decrease fuel consumption and increase thrust. Thus the Air Force funded several programs to develop engine components and to test demonstrator engines before the C-5A development was begun. It was believed then that the technical difficulties had been identified and assessed before contractor commitments were made. (44:28) However, other major technical uncertainties, specifically with the airframe, were poorly identified, thus causing design deficiencies, weight problems and the resulting cost overruns. (36:151-164)

DTC and Technological Uncertainties

Cost-benefit analysis is an important aspect of the design-to-cost concept. One of the principal factors of the concept is that benefits from increased performance characteristics must justify the increased costs of production. However, it is difficult to design a system to a cost constraint if the technology is not well in hand. (86) Further, the higher the technological risk, the more difficult it becomes to employ DTC. Yet DTC can be utilized in systems requiring new technology provided there is an adequate development effort before entering production. (94) Such an effort would require increased development time and increased development funds. Where prototyping is feasible, program managers can obtain improved performance and cost data, thus determining the ability to meet the cost constraint.

Design-to-cost, hence, best lends itself to programs which utilize existing technology. Advanced system programs can utilize DTC, but the development time and budget will necessarily have to be increased to eliminate major uncertainties. For advanced systems, DTC appears to be best applied on a subsystem or component basis. However, this may create problems of subsystem interfaces and total system costs may increase more than estimated. It is interesting to note that most of the systems utilizing DTC are ones which require the use of existing technology or limited increments in technological development. Without an adequate development effort preceding production to eliminate major technological uncertainties, DTC will suffer the same limitation as TPP.

Urgent Need

Total package procurement required that firm price, schedule, and performance commitments be written into the contract. Therefore vigorous contract definition activities to inhibit subsequent contract changes and adequate development research to identify major technological uncertainties had to precede award of the contract. Both of the activities are time-consuming, thus limiting the use of TPP in procuring systems for which an urgent need exists.

DTC and Urgent Need

One of the reasons for cost growth in past weapon procurements has been due to concurrency. (79) DTC emphasizes that major technological uncertainties must be resolved prior to a production decision. Without time for adequate development there is little certainty that the unit cost goal can be attained. Consequently, the concept requires that an adequate full scale development effort be completed before entering production. As previously noted, then, design-to-cost is similar to total package procurement and is subject to the same limitation of non-concurrent development.

Summary

It is apparent that some of the limitations of total package procurement are potential limitations of the design-to-cost concept. These limitations exclude its application to (1) system programs with uncertain mission requirements, (2) programs with major technological uncertainties, and (3) systems which are urgently needed.

Total package procurement has been castigated as a result of the C-5A experience. A study of the application of TPP to that acquisition cites four main factors contributing to the failure of the program: (1) inadequate design, (2) inadequate development time, (3) technological uncertainties, and (4) permitted "buying-in" by the contractor on the part of the government. (36:151-171) Ironically, three of these are factors which limit the use of the concept.

In retrospect, it is erroneous to assert that TPP is a poor procurement philosophy. The problems resulting in military procurements using TPP were caused more by its misapplication rather than any inherent deficiencies. (36:169)

A major problem arises when one particular concept is applied universally.

> One of the faults of large organizations which are responsible for development activities is that they tend to seek a single development policy that is appropriate to all development, at all times, and with all contractors. Moreover, these procedures frequently are more nearly oriented to meeting the needs of the bureaucratic organization responsible for the development than to meeting the needs of the development project at hand. (21:21)

The limitations of any procurement concept should be identified, and the error of attempting to apply it to all acquisitions should be avoided. Thus, in implementing design-to-cost, DoD must be cognizant that there may be procurements for which DTC is not applicable.

From the authors' research, it is evident that system program offices throughout the services are attempting to employ DTC. This is in accordance with DoD Directive 5000.1. The authors assert that the concept has merit if appropriately applied. However, the authors hypothesize that the concept may prove inadequate by DoD insistence on a single procurement policy, a policy which does not recognize the inherent limitations of the concept as applied to some programs.

Having concluded that some of the limitations of total package procurement are potential limitations of design-to-cost, the authors will now address some considerations for more effective use of the DTC concept in answering the final research question.

CHAPTER IV

SOME CONSIDERATIONS FOR MORE EFFECTIVE USE OF THE DESIGN-TO-COST CONCEPT

In order to enhance the successful use of the design-to-cost concept, the authors raised the question, "How can the use of the design-to-cost concept be improved?" In answering this question, several considerations for increasing the effectiveness of DTC have been determined. Seven major topics are presented below in the following order: (1) the fallacy of one institutional strategy, (2) uniform unit production cost definition, (3) extended use of competition, (4) the need to maintain tradeoff opportunities, (5) adjustments in the ceiling price, (6) personnel motivation and recognition, and (7) the need to recognize the multiple goals of the defense industry in incentivizing design-to-cost contractual provisions.

One Institutional Strategy?

There is a concern among many military program managers that design-to-cost will "become 'institutionalized,' complete with a 'do-it-yourself' design-to-cost kit." (64) The propensity of large organizations to select the one "best" policy to be applied to all situations has already been alluded to in this study.

Part of the reason DoD attempts to simplify the procurement strategy decision to one or a few alternatives is due to the discontinuity of program management caused by the military personnel rotation and promotion cycle. Iron-clad rules and specifications have been sought to provide program management continuity in an attempt to correct the lack of stability in program leadership. (38:25)

A variety of different concepts for major weapon system acquisitions should be sought, since each particular concept has its relative advantages and disadvantages. The particular procurement strategy chosen should be tailored to the characteristics of the program at hand. "One should not simply and blindly choose whatever strategy is most in vogue at the moment." (22:2)

The particular concept chosen to be employed should be based on such program features as expected production quantities, technological and strategic uncertainties, urgency of need, cost implications of the strategy, feasibility of competition, and technological advances sought. Thus the merits and difficulties of each procurement strategy should be examined because no one strategy is appropriate for all acquisition programs.

In 1969 a research study on the interactions of procurement decisions cautioned that

> ...despite the substantial merits of TPPC (total package procurement concept), it would be regrettable if it were to become a new orthodoxy. On the other hand, it would be regrettable if difficulties with some programs to which TPPC has been applied lead to dropping this technique from the arsenal of strategies. (22:15)

However, such has been the case. DoD Directive 5000.1 states that major defense systems "will not be procured using the total package procurement concept." (56:5)

In order to make effective procurement decisions in the future, DoD must maintain an "arsenal of strategies." Before one particular concept is chosen to be employed, its relative merits and disadvantages must be examined. Just as advocates of total package procurement cautioned that judgment must play a major role in determining if TPP should be used in a particular system acquisition, the same caution must be applied in using design-to-cost. The previous chapter established the fact that design-to-cost will not alleviate all the major deficiencies of TPP. Thus DoD executives must be cognizant of the limitations of seeking one best procurement strategy to be applied to all acquisitions. For design-to-cost to be successful, DoD must resist the desire to apply it to all programs.

Uniform Production Cost Definition

As noted in Chapter II, programs implementing the concept consider the cost of design-to-cost as the unit production cost. However, there appears to be no general consensus as to what costs should be included in the unit target. There is a particular disparity as to the inclusion of non-recurring costs and profit.

There are basically two views concerning the inclusion or exclusion of non-recurring costs in the unit target. Proponents for inclusion of non-recurring costs cite two reasons. First, inclusion permits a greater ability to examine alternative production methods, since the production method depends on the quantity required and the design characteristics of the system. Knowledge of non-recurring costs is particularly important in decisions concerning the type of tooling to be employed in the manufacturing process. By including the non-recurring cost elements, the contractor and the government can determine the quantity breakeven point where it becomes more economical to employ specialized equipment rather than general purpose tooling. Second, if, as DoD states, an improved data base for parametric costing is to be constructed, the non-recurring portion needs to be included. In the past, these elements have contributed to a portion of the cost growth associated with weapons acquisition. For DoD to procure systems within cost constraints, it must know the effect of these non-recurring cost elements on total production cost.

Those who favor limiting the target cost to only the recurring production costs cite three reasons. First, it is frequently difficult to determine what all of the non-recurring cost elements are. Second, it is frequently difficult to quantify these cost elements once identified. Third, where joint costs are concerned (e.g. the salary of a manager overseeing two production programs), there may be no rational method for cost allocation. Any allocation that is undertaken is arbitrary and serves no useful purpose in price making.

There are also basically two views on including profit in the unit production cost. The first view holds that since profit does result from the production contract and is part of the total cost to DoD, it should be included in the unit production cost target and charged against the items produced. The opposing view states that profit should be excluded, since profit is normally a function of the type of contract negotiated. Thus, in preparing a data base, only the costs to the contractor should be included, since these will be only valid costs that should be used in arriving at a cost estimate to predict future systems costs.

DoD officials have stated that the incremental decision strategy requires that viable alternatives be maintained until the system selected for deployment has demonstrated required performance and cost characteristics. For alternatives to be comparable and for design-to-cost to be meaningful, a uniform definition for production cost is needed. Therefore, it is essential that DoD determine the cost elements to be considered in the unit production cost.

Competition

In comparing the competitive situation in defense and commercial practices, one realizes that the current competitive environment in military procurements is almost the reverse of that in commercial industry. In commercial practice, competition begins with program commitment. At this time, the manufacturer is motivated to improve product quality and reduce price to gain volume follow-on orders. However, in the defense industry, competition occurs during the formulation of requirements and before program commitment. After program award, there is less competition since there is usually only a single contractor.

Although there are many incentives and variables which influence the ultimate price of a weapon system, competition can often be more effective than any other incentive. Competition threatens the contractor with potential loss of business which can impact upon his organizational stability or continuity. Hence, competition can often be a stronger motivator than maximization of profit or revenue. Key business leaders serving on the Defense Science Board Task Force on Reducing Costs of Defense Systems Acquisition felt that competition would provide a beneficial impact on design-to-cost if competition could be extended over a greater period of the program's life. (38:2-3) In addition, the Navy has realized that program managers should "ensure that technical [i.e., hardware] competition is utilized to the maximum extent possible." (64) Progress toward this goal is currently being made by using competition during the operational prototype phase. The merits of competition can be exemplified by the benefits realized in two competitive prototype programs, the Airborne Warning and Control System (AWACS) Program and the A-X Close Air Support

Aircraft.

In stating the effects of competing with Hughes on the AWACS Program, The Boeing Company stated:

> Without the stimulus of the competitive environment, we feel it would have been impossible to motivate either contractor to the level achieved.... Program estimates range up to 100 million more dollars for 25% less performance if we had gone with only one radar contractor. (38:4)

Competition also played a major role in the A-X prototype development. Colonel James E. Hildebrandt, A-10 program director, has stated:

> There is no question in my mind that the (Fairchild) A-10 would cost more...if it hadn't had competition from the (Northrop) A-9. I am quite sure Fairchild would have gone more for optimizing performance if it hadn't had competition to hold the cost down. And we probably wouldn't have gotten the energetic GE (General Electric) cost reduction effort, if they hadn't had competition from the lower-cost Avco engine. (15:49)

In addition to competition among contractors, the winning firm must be made to realize that the system it is developing still faces competition from other alternative systems. For example, the A-10 still faces competition from the combat-proven A-7, and before the production decision is made on the A-10, all alternatives available to DoD will be examined. (82) Although some business executives feel competition from other program alternatives is only indirect (38:3), such competition can have the effect of motivating the contractor to remain within the cost constraint if DoD proves to be credible in its intent of examining all alternatives fully. This also requires that DoD consider program termination as a viable alternative.

One final aspect of competition should be examined. Dual, competing program offices during the initial conceptual and prototyping phases may further stimulate design-to-cost solutions to new systems acquisitions. (38:6)

The cost of competing contractors, systems, and/or program offices must be examined to determine if the benefits derived from such competition are justifiable. However, in many instances, competition can make a beneficial impact on design-to-cost implementation, since competition will often be a more effective motivator on the contractor or program manager than any other incentive or variable.

Tradeoffs

Historically, one of the problems associated with program development is the assumption that, once approved, the plan, including the system's requirements, is unchangeable. However, for design-to-cost to be a viable procurement philosophy, program requirements must be flexible in order to provide tradeoffs to meet the cost constraint. "To regard stated program requirements as 'untouchable' at or after program approval would be to miss a major portion of the trade-off opportunities." (38:11) Since the knowledge necessary to recognize tradeoff opportunities does not exist when the program is initially approved, the option of making such tradeoffs should be retained. Each element of the program's plan should be developed in an iterative process until it can be merged compatibly with other elements to meet the realistic cost objective. Thus the program's plan should be iterative. All requirements developed at the beginning of the program should be reviewed or revised periodically to insure that their relative value is still being attained. (38:11)

The official U. S. Navy position on design-to-cost recognizes the need to maintain tradeoff flexibility. Acquisition managers should "be fully prepared to make the technical and schedule tradeoffs necessary to stay within the established cost figure." (64) In addition, the General Accounting Office, in studying the acquisition of major weapon systems, has recommended that the ability to make tradeoffs be maintained throughout the acquisition process. (63:56)

As noted in Chapter II, the present implementation of design-to-cost is not totally consistent with DoD Directive 5000.1 since production costs are currently the only "design-to" costs. A major fear of program managers implementing the concept is that production costs will be emphasized at the expense of total life cycle costs. (64) Some feel that reliability and maintainability factors will be sacrificed or deemphasized to meet the production cost goal. Their view is that DTC may result in higher operational and support costs, since designing a system to meet a unit production cost target does not necessarily assure that the costs associated with its field use will be less. For example, a system which is designed-to-cost may be more reliable because it has a simpler design; however, it may have low maintainability. Hence, poor availability may be the result and total life cycle costs may increase.

An example of the conflict that can develop between achieving lower production costs and considering logistic factors can be seen in the development of the A-10A. One of the principal aims of the A-10A program is to develop a system which can be maintained easily in the field. Construction of the aircraft's wing as a single unit would have resulted in lower unit production costs. However, this would have presented several support problems. Should depot repair have been needed, few aircraft would have had the capability to transport the wing from the field. As a single unit, the wing would have been approximately 60 feet in length. It would have required special support equipment for removal and installation which the program office wanted to avoid. Further, the unitary construction would have complicated maintainability when it became necessary to repair damaged sections. For these reasons, the program office elected to have the wing constructed in three sections. This complicated the wing's design and at the same time increased aircraft unit production costs. However, program personnel maintained that greater cost savings would accrue from decreased support costs of the system. Had the program opted simply for the decreased unit production costs, these later cost savings might not have been realized. (77)

To date, placing ceilings on the unit production cost appears to have resulted in designs which are simpler and which can be maintained and operated at lower costs, thus providing lower total life cycle costs. (17) In balancing performance and costs in prototyping the A-10, Fairchild Industries went to proven subsystems. "The result was that our airplane is designed not with the latest, but with proven, low cost, reliable subsystems." (45) Similar tradeoffs were made in the SCAD program in which requirements that drove system design, program schedule and acquisition costs were reviewed and possible tradeoffs to hold to the cost objective were identified. (9)

In designing-to-cost, tradeoff opportunities must be identified. Such tradeoffs will generally result in simpler designs which, in turn, may provide lower life cycle costs. Careful analysis must be given to tradeoffs in operational and support areas to insure that total life cycle costs themselves are not traded off to achieve the unit production cost target.

Adjustments in the Ceiling Price

Design-to-cost is a means of countering high unit production cost and unnecessary system sophistication and complexity. However, determining the right ceiling price that the system should be "designed-to" is a difficult task, since it relies on early cost estimates. DoD officials state that "early cost estimates are necessarily rough" (17) and that the Defense Department has never been able "to accurately estimate the true costs of a weapons system at its inception." (42) Thus the problem arises as to what action DoD should take if the "wrong" ceiling is established as the unit production cost target. When DoD initially establishes the cost ceiling, all calculations and assumptions should be recorded. These assumptions should include production quantities and rates, learning curves, the time period and assumed inflation rate if constant dollars are not used. If the assumptions change, then perhaps the ceiling should be adjusted to reflect this change. However, such a change in the ceiling should not be interpreted as a relaxation of the design-to-cost philosophy, since it is a correction in the admittedly incorrect, original cost estimate. (17)

DoD officials state that poor government "cost estimating has not been the dominant factor in cost increases. Abuse of the 'requirements' process is the more likely culprit." (42) Higher costs for new requirements which do not greatly increase the mission capabilities of the system being designed are not adequate justification for changing the design-to-cost target. However, adjusting the ceiling price to reflect changes in original program assumptions should not be interpreted as relaxing the design-to-cost objective. Therefore the flexibility to make such a change should be retained by DoD.

Personnel Motivation and Recognition

Corporation executives themselves do not design-to-cost. Though executives from major defense contractors have extolled the benefits to be achieved from use of the concept, it is the individual design engineers who will ultimately determine the success or failure of design-to-cost.

The concept requires careful management by both the contractor and the government. As with any management concept in which there is a desired outcome, subordinates within the organization need to be motivated to meet that goal. In the past, design engineers have been motivated to meet and exceed performance requirements. Now the viewpoint has changed. Design engineers, as well as the myriad of other personnel involved in a defense acquisition, must be motivated to achieve performance characteristics necessary for the system to fulfill its assigned mission at a cost which is acceptable to the government. For the concept to be successful, the personnel involved in the development and acquisition process must be oriented to both cost and performance goals. This motivational process requires a system which recognizes personnel for their contributions to these goals. This system of recognition must not only emphasize an individual's contribution to improved technical capabilities, but must also emphasize the individual's contribution to more cost effective systems. This is not an easy process, nor is it solely the responsibility of the lower echelons within the defense contractor's plant. To be effective, the concept and more specifically, the motivational process must have continuous support from all levels of the contractor's organization, the overall defense industry, and the Department of Defense. David N. Burt, Assistant Professor of Logistics Management, Air Force Institute of Technology, contends that DoD should consider increased use of the award fee as a means of motivating contractor personnel. (73)

Defense Industry Goals and Influences

In the past, the assumption underlying most system acquisition contracts has been that the defense contractor is a profit maximizer. Consequently, government contracts have attempted to motivate the contractor to achieve greater technical, schedule, and/or cost effectiveness on the basis of increased profits. Recently, however, the profit maximizing assumption has come under considerable attack from several sources. (72) Several economists contend that the defense industry is revenue oriented rather than profit oriented, and therefore past contractual mechanisms will not adequately motivate the contractor.

As with any complex entity, the objectives of a defense contractor are diverse and not limited solely to profit. Various sources have attempted to list the multiple goals of the defense industry. These include company growth, market share, public image and prestige, opportunity for follow-on business, application of product to the commercial market, and utilization of available skills and capacity. (61:249)

In his 1972 doctoral dissertation, George David Broyles, Executive Assistant to the Secretary of the Air Force (Installations and Logistics), contends that the environment in which aerospace contractors operate is conducive to unrealistic initial cost estimates and subsequent system cost growth. (10:55-75) He notes that because of the present overcapacity within the aerospace industry, the multiple objectives of defense firms, and the monopsonistic power held by the government, contractors are motivated to submit unrealistically low cost proposals to obtain system contracts. However, once a contract is awarded, the monopsonistic power held by the DoD is substantially diminished as contractor competition is virtually eliminated. The contractor is therefore motivated to take action which increases costs thus increasing revenue on cost reimbursement contracts or calling for renegotiation of subsequent fixed price contracts.

According to Broyles, defense contractors have three primary reasons for taking action to increase revenue. First, the firm has a highly paid pool of salaried professionals which must be kept in tact for follow-on business and to maintain the technological expertise necessary for remaining competitive in the market. Keeping this labor force in tact requires a constant cash flow to pay salaries. Next, due to the high risk associated with weapon system development, long term credit is hard to obtain. Therefore, firms can usually only get short term credit at high interest rates, thus necessitating a high cash turnover. Finally, since a prime contractor usually has many subcontractors, payment to subcontractors causes a constant drain on cash flow. (10:105)

Since the defense industry may be motivated by benefits other than profit, program managers must recognize what these influences are in incentivizing design-to-cost contractual provisions. For example, the AMST prototype contract signed with McDonnell Douglas is structured on a cost sharing basis, whereas the Boeing contract is a cost plus fixed fee. McDonnell Douglas is willing to invest its own corporate funds in the prototype development since its YC-15 aircraft might have some application in the commercial market. Thus an incentive provision not recognizing this fact would be less effective.

Dr. Raymond G. Hunt, Professor of Psychology, State University of New York at Buffalo, has suggested that government contracting procedures decrease their emphasis on complex multiple-incentive formats with their reliance on economic rewards and penalties. Instead government contracting methods should strive to establish an interdependent rather than an independent, possibly counterproductive, relationship between the procuring agency and the contractor. Thus, what is needed is "a managerial instead of a mechanical approach to procurement and R&D project management." (11:77-78)

In implementing design-to-cost in system acquisitions, DoD program managers must recognize the multiple goals of the defense industry. Other industry goals may be more important than just profit alone. Thus for design-to-cost to be effective, these other influences must be considered when structuring both development and production contracts.

Summary

Design-to-cost has merit as a procurement strategy for the

1970's since its objective is to counter high unit production costs and unnecessary system sophistication and complexity. Before design-to-cost is implemented in a new weapon system acquisition, its relative advantages and disadvantages pertaining to that particular program must be examined. In addition, the above seven factors for more effective use of the design-to-cost should be considered in implementing the concept.

CHAPTER V

PRÉCIS

Design-to-cost requires that DoD establish a unit production cost which it can afford to pay for the quantities of weapon systems needed. As noted in Chapter I, the use of the concept in weapon system acquisitions requires attention to four key elements. These include (1) the system cost target, (2) the system performance goals, (3) the production plan, and (4) a feedback mechanism.

In examining the use of design-to-cost in weapon system acquisitions, the authors posed these three questions:

Research Question #1. What is the current status of design-to-cost implementation?

Research Question #2. Does the design-to-cost concept alleviate the deficiencies encountered in total package procurement?

Research Question #3. How can the use of the design-to-cost concept be improved?

A concise summary of the essential points, statements, and facts presented in answering each research question is provided below.

What Is the Current Status of Design-to-Cost Implementation?

Publication of DoD Directive 5000.1 in 1971 formally established the design-to-cost concept within the Department of Defense. The directive requires the establishment of cost parameters which consider both the cost of acquisition and ownership. It is apparent, however, that the design-to-cost concept is being implemented principally on the basis of system unit production costs rather than using a life cycle cost approach. Although there is general agreement that design-to-cost can be implemented meaningfully only on the basis of system production costs, there is no agreement as to the cost elements that should constitute the unit production cost target. Some of the contracts examined included only recurring production costs while others included recurring and nonrecurring production costs. Still others provided an allowance for profit in the unit cost target.

One of the major characteristics of the programs implementing design-to-cost is the lack of strict system performance requirements. Almost all performance requirements are expressed in terms of goals; however, cost is considered the most significant "goal."

At present there is no common method for implementing the concept in development contracts nor is this required. The method for the concept's implementation depends upon the system under development, the desired state-of-the-art in technology, the ability to trade off performance requirements, and the degree of competition prevalent during development.

Several of the development contracts (e.g., B-1 RFS/ECM, UTTAS, SAM-D) examined provide for increased contractor fee on a subsequent production contract should the contractor achieve a unit production cost lower than the cost objective. It is not clear at this time how the contractor would be rewarded for achieving a lower unit production cost if the system, for some reason, should not be approved for production. This poses a dilemma for the contractor, particularly when he may have to exceed the target development cost (and thus share in or assume all further development costs) in order to achieve the production cost objective. Further research is needed in determining how to reward contractors for achieving the cost objective if a production contract is not awarded.

Does DTC Alleviate the Deficiencies Encountered in TPP?

DoD developed design-to-cost as part of the incremental acquisition policy which replaced the total package procurement concept, the procurement policy of the latter 1960's. In comparing design-to-cost and total package procurement, the authors found that the concepts are similar in several respects. The main differences between the two are primarily attributable to the incremental decision strategy employed by DoD in using design-to-cost. After reviewing both concepts, it appears that some of the limitations of total package procurement which exclude its application in certain situations may also be potential limitations of design-to-cost. These limitations may exclude its application to (1) system programs with uncertain mission requirements, (2) programs with major technological uncertainties, and (3) systems which are urgently needed. As with total package procurement, design-to-cost may not be applicable for some system acquisitions.

<u>How Can the Use of the Design-to-Cost Concept Be Improved?</u>

In posing the third research question, the authors addressed several considerations for increasing the effectiveness of design-to-cost.

The problem of attempting to apply design-to-cost to all acquisition programs was discussed. DoD must maintain an "arsenal of strategies," since each particular procurement concept has its relative advantages and disadvantages. Before a particular concept is chosen to be employed, its relative merits and limitations must be examined. Just as advocates of total package procurement cautioned that judgment must play a major role in determining if TPP should be used in a particular system acquisition, the same caution must be applied in using design-to-cost. For design-to-cost to be successful, DoD must resist the desire to apply it to all programs.

In addition to the problem of one institutional strategy, the need for program requirements to be flexible in order to provide for tradeoffs to meet the cost constraint was examined. Such tradeoffs will generally result in simpler designs which, in turn, may provide lower life cycle costs. However, careful analysis must be given to tradeoffs in operational and support areas to insure that total life cycle costs themselves are not traded off to achieve the unit production cost target.

The need for flexibility to make adjustments in the ceiling price should the basic assumptions of the original cost estimate change was also considered. However, such adjustments should not be interpreted as relaxing the design-to-cost objective. For example, if the number of units to be produced is reduced, this may require a change in the unit target cost. As fewer units are produced, non-recurring costs will assume a greater proportion of the overall unit cost. In addition, benefits from the experience curve phenomenon will not be as significant.

In implementing design-to-cost in system acquisitions, DoD program managers must recognize the multiple goals of the defense industry. Other goals than just profit alone may be more important. Extracontractual influences must be considered when structuring both development and production contracts.

Extended use of competition, the need for a uniform definition of unit production cost, and personnel motivation and recognition were also considerations addressed in Chapter IV.

Concluding Remark

The newness of design-to-cost in DoD acquisitions prevented the authors from making a quantitative evaluation of the success of the concept. The authors recommend that the concept be reexamined when the results of several system programs using design-to-cost are known. However, since there is presently limited information concerning the concept and its application to military procurement, this study should prove beneficial to DoD managers as they are attempting to implement design-to-cost.

APPENDIX A

STRUCTURED INTERVIEW GUIDE

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STRUCTURED INTERVIEW GUIDE

1. What is the definition of "cost" in the term "design-to-cost?" What cost elements does this definition include?

2. What tradeoffs are required in implementing design-to-cost?

3. What impact will design-to-cost have on acquisitions requiring increases in the state of technology?

4. How is design-to-cost being contractually implemented?

5. Will design-to-cost be an improvement over total package procurement? Why or why not?

6. What role does competition play in the use of design-to-cost?

7. What impact does design-to-cost have on system development time?

8. What can be done to improve the implementation of design-to-cost?

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DESIGN-TO-COST: AN EXAMINATION OF ITS USE IN WEAPON SYSTEM ACQUISITIONS

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The design-to-cost concept is an integral part of the system acquisition policy recently implemented by the Department of Defense (DoD). However, a great deal of uncertainty exists as to what the term "design-to-cost" means. Although DoD officially views life cycle costs as the "design-to" costs of the concept, the authors, after examining several system programs, conclude that the concept is being implemented instead on the basis of system unit production costs. Even though there is a general agreement among system program personnel that design-to-cost refers to unit production costs, there is no clear definition as to what cost elements the production cost should include. Nor does there appear to be any common method for implementing the concept in development contracts.

DoD developed design-to-cost as part of the incremental acquisition policy which replaced the total package procurement concept, the procurement policy of the latter 1960's. In several respects, the two concepts are similar; the differences are primarily attributable to the incremental decision strategy employed by the DoD in using design-to-cost. After reviewing both concepts, the authors conclude that the limitations of the total package concept are potential limitations of design-to-cost. The authors state that as with total package procurement, design-to-cost may not be applicable for some system acquisitions. Design-to-cost may prove to be inadequate because of DoD insistence on a single procurement policy, a policy which does not recognize the inherent limitations of the concept as applied to some programs. Finally, the authors present several areas which require further consideration and analysis for the implementation of the concept to be successful.